

The system of the sensory supply is examined in detail. It is shown to follow a law composed of two rules:—

III. A. *Of two spots on the skin, that which is nearer the preaxial border tends to be supplied by the higher nerve.*

B. *Of two spots in the preaxial area, the lower tends to be supplied by the lower nerve, and of two spots in the postaxial area, the lower tends to be supplied by the higher nerve.*

It is shown that this is the case with all membranes stretched into a sheath by something pushing out into them, and the epiblastic layer of the epidermis is compared to such a membrane, pushed into a tubal sheath by the developing mesoblast.

A note is added showing that other observers have reached similar results by other methods, and notably that Forgue has formulated laws for the motor nerves of the monkey, identical with those laid down in the present paper.

II. "On the Changes produced by Magnetisation in the Length of Iron Wires under Tension." By SHELFORD BIDWELL, M.A., LL.B. Communicated by Professor F. GUTHRIE, F.R.S. Received March 10, 1886.

In a paper communicated to the Royal Society about a year ago,* I discussed the results of certain experiments made by Joule in relation to "the Effects of Magnetism upon the dimensions of Iron and Steel Bars."†

It is well known that the length of an iron rod is in general slightly increased by magnetisation. Joule enunciated the law that the elongation is proportional in a given bar to the square of the magnetic intensity, and that it ceases to increase after the iron is fully saturated.‡ My own experiments, made with a greater range of magnetising forces and with thinner rods than those used by Joule, show that if the magnetising current is gradually increased after the so-called saturation point of the iron has been reached, the elongation, instead of remaining at a maximum, is diminished, until when the current has attained a certain strength, the original length of the rod is unaltered, and if this strength be exceeded, actual *retraction* is produced.

Joule also found that when the experiment was performed upon an iron wire stretched by a weight, the magnetic extension was in all

* "On the Changes produced by Magnetisation in the Length of Rods of Iron, Steel, and Nickel." "Proc. Roy. Soc.," vol. 40, p. 109.

† "Phil. Mag." [3], vol. xxx, pp. 76, 225, and the Phys. Soc.'s Reprint of Joule's Scientific Papers, p. 235.

‡ Reprint, pp. 245, 255.

cases diminished, and if the weight were considerable, magnetisation caused retraction instead of elongation. From these facts he appears to have formed the conclusion that, under a certain critical tension, (differing for different specimens of iron, but independent of the magnetising force) magnetisation would produce no effect whatever upon the dimensions of the wire. In one of his experiments* a certain iron wire loaded with a weight of 408 lbs. was found to be slightly elongated when magnetised; the weight was then increased to 740 lbs. with the result that magnetisation was accompanied by a slight retraction. In both cases the magnetising currents varied over a considerable range, and the smaller ones were without any visible effect. Commenting upon these results, Joule conjectured that "with a tension of about 600 lbs. [which number I suppose is selected as being roughly the mean of 408 and 740] the effect on the dimensions of the wire would cease altogether in the limits of the electric currents employed in the above experiments."†

In reference to this surmise‡ I ventured the following remark:—"If he had actually made the experiment, he would perhaps have found that the length of the wire was increased by a weak current, that a current of medium strength would have had no effect whatever, and that one of his stronger currents would have caused the wire to retract." I had, in fact, reason to believe that the effect of tension was to diminish the "critical magnetising force" (which produces maximum elongation) so that the retraction which is found to occur in all iron rods when a sufficient magnetising force is employed, is observed with smaller magnetising currents when the rod is stretched than when it is free,§ but want of suitable apparatus prevented me from submitting this idea to the test of direct experiment.

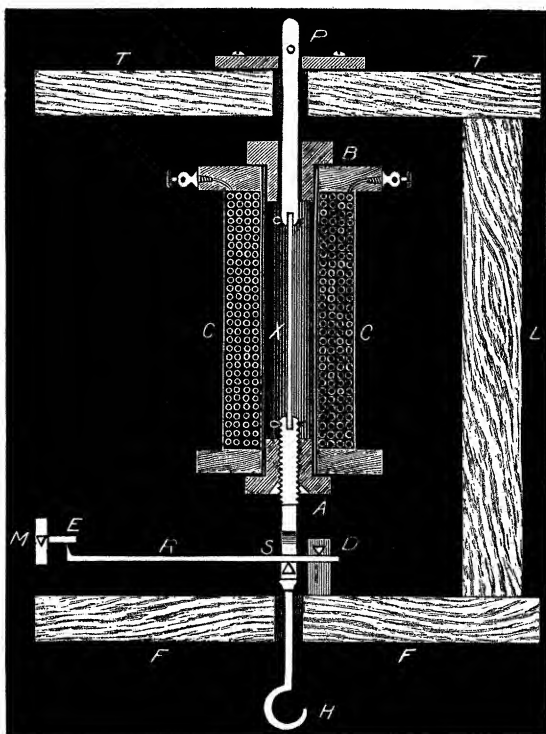
I have lately modified the instrument, which is described in my former paper, in such a manner that it can be used for observing the effects of magnetisation upon rods and wires under traction. The working part of it is shown in diagrammatic section in the annexed figure. The coil CC contains 876 turns of copper wire, 1·22 mm. in diameter, wound in 12 layers on a brass tube with boxwood ends. To the lower end A of the tube is fitted a brass plug or stopper, having

* Reprint, p. 254.

† These currents produced deflections ranging from 6° to 58° on his tangent galvanometer, which "consisted of a circle of thick copper wire one foot in diameter, and a needle half an inch long furnished with an index."

‡ Joule's conjecture is sometimes quoted as if it were an experimental fact. See Chrystal's article on Magnetism, "Enc. Brit.," vol. xv, p. 269.

§ My belief was principally founded upon the fact that while the critical magnetising force appeared in all the cases which I had examined to be about twice that corresponding to the "turning-point" in the magnetisation curve, the turning-point itself occurred at an earlier stage when the wire was stretched than when it was unstretched.



an axial hole drilled through it, which is tapped to receive a screwed brass rod terminating in a stirrup S. The bottom of the stirrup is formed like a knife-edge with the edge uppermost, and beneath it is fixed a hook H, from which weights may be suspended. A second perforated stopper B is fitted to the upper end of the tube; the hole through this is left smooth and freely admits a brass rod, which is suspended by means of a pin at P from a thick brass plate attached to the mahogany table T. The height of P can be varied within small limits by means of a fine screw adjustment, not shown. The table T is attached to the base-board F of the instrument by three stout legs, only one of which, L, appears in the diagram. The wire under experiment, X, is clamped at its two ends between slits in the ends of the brass rods P and S, and thus supports the coil in an upright position. By turning the screwed plug A the position of the wire X may be so adjusted that its middle point shall coincide with that of the axis of the coil.* The knife-edge of the stirrup acts upon the brass lever R, one end of which abuts upon a fixed fulcrum D, while the other

* Exact coincidence is not essential.

actuates a short arm E attached to the back of a small circular mirror M; the mirror is capable of turning about its horizontal diameter upon knife-edges, resting upon brass planes not shown in the figure. By means of a lantern illuminated by a lime-light, the image of a horizontal wire is, after reflection from a mirror, projected upon a distant vertical scale; a very slight deflection of the mirror causes a considerable movement of the image. The dimensions are as follows:—The distance SD = 10 mm., SE = 170 mm., ME = 7 mm.; the distance from the mirror to the scale = 6400 mm., each scale division = 0.64 mm., and the length of the experimental rod between the clamps = 100 mm. The movement of the focussed image through one scale division therefore indicates a difference of about one five-millionth part* in the length of the rod. The mirror is very accurately worked, and is silvered upon its outer surface; the lens used for the projection is a compound achromatic of high quality, and it is easy to read with accuracy to a half or even a quarter of a scale division.

The magnetising coil is 11.5 cm. long between the boxwood ends; its external diameter is 5.2 cm. and internal diameter 1.9 cm. A current of C ampères produces at its centre a field of about 92 C units.

It will be seen from the above description that the wire under examination sustains the whole weight of the magnetising coil as well as that of the lever R. In order to ascertain the amount of the tension thus produced, the brass rod P was suspended from a hook beneath one pan of a large balance, and it was found that in order to maintain the lever R in a horizontal position it was necessary to place weights amounting to slightly more than 3 lbs. in the other scale pan. In all experiments with this apparatus, therefore, the iron wire is stretched by a minimum initial load of 3 lbs. For some reasons this is a disadvantage, and the arrangement in question was not adopted until many experiments had made it evident that by no other method was it possible to avoid with certainty the source of error introduced by the electromagnetic action commonly known as solenoidal suction between the coil and the wire. When the coil is fixed independently of the wire, the smallest trace of this action produces upon the lever an effect which is enormously exaggerated in the deflection of the image upon the scale. The wire may be placed as accurately as it is possible to do so by measurement, with its middle point in the centre of the coil; but a change in the stretching weight will at once displace it to a small but material extent; and even if the geometrical coincidence were perfect, a slight want of uniformity in the physical qualities of the wire would still render the objectionable action possible. Under ordinary circumstances the

* More exactly 0.00000020588.

disturbance thus introduced would of course be altogether insensible; but in making measurements in which a hundred-thousandth of a millimetre is a considerable quantity, it is far from negligible, as indeed was sufficiently proved by the inconsistency of the results obtained in some of my earlier experiments when the wire was free and the coil attached to the table T.* After the coil had been suspended upon the wire all such inconsistency at once disappeared, for no interaction between the two could then produce any external effect.

Since the apparatus was not calculated to bear any very heavy weight it was necessary to use wires of small sectional area. Thin wires moreover possess an advantage in becoming more strongly magnetised by a given current than thick wires of the same length.

The results of a series of experiments are presented in a synoptical form in the subjoined Table. Four specimens of iron were used. The first was a wire of commercial iron, 1.2 mm. in diameter, which had been softened by heating in a gas flame; the second was a strip of annealed charcoal iron, 5.5 mm. wide and 0.55 mm. thick, its sectional area being about 3 mm.; the third was a piece of hard unannealed wire, 2.6 mm. in diameter; and the last was a wire of very pure soft iron, 3.25 mm. in diameter, which had been carefully annealed. These were successively fixed in the apparatus, and loaded with weights varying from 3 lbs.—that of the coil and lever alone—to a total of 14 lbs. While under the influence of each load, four observations were made in the case of each wire: (1) A determination was attempted of the smallest magnetising current which sensibly affected the length of the wire in the direction of elongation or retraction. (2) The current producing *maximum* elongation (if any), and the extent of such maximum elongation were found. (3) A determination was made of the critical current which was without effect upon the original length of the wire, *i.e.*, the current of such strength that a weaker one would cause elongation and a stronger one retraction. (4) The retraction produced by a fixed current of 1.6 ampère was measured.

The first operation, that of finding the smallest current which produced a sensible deflection, was not easy to perform satisfactorily. Small differences in the disposition of the lever and mirror might

* The same source of error troubled me much in the experiments described in my former paper until I adopted a similar method of avoiding it. The apparatus used by Joule was far larger, more massive, and presumably less delicate than mine. In the instrument employed in his stretching experiments the lever alone without any additional weight produced a tension in the wire of 80 lbs. Errors arising from solenoidal suction would therefore be less sensible, but it is difficult to believe that some of his results were not affected by them, especially in the case of the experiment (No. 8) on hard steel described at p. 245 of the Reprint, which I believe no one has succeeded in repeating.

Table.

	Commercial iron wire, diam. 1·2 mm.				Charcoal iron strip, section 3 mm.				Hard wire, diam. 2·6 mm.		Soft wire, diam. 3·25 mm.	
	3 lbs.	7 lbs.	10 lbs.	14 lbs.	3 lbs.	7 lbs.	10 lbs.	14 lbs.	3 lbs.	14 lbs.	3 lbs.	14 lbs.
Stretching load												
Smallest current producing sen- sible elongation	0·043	0·064	0·084	..	0·033	0·020	0·029	0·064	0·12	0·15	0·064	0·033
Current producing maximum elongation.....	0·49	0·39	0·23	..	0·44	0·33	0·27	0·15	0·70	0·58	0·70	0·58
Current by which original length is unaffected.	0·99	0·73	0·47	0·23	1·30	0·99	0·77	0·53	0·99	0·94	1·24	1·09
Maximum elongation in scale divisions	2	1·5	0·5	..	10	6	4	1	2·5	2·5	6·5	4·5
Retraction with current of 1·6 ampère	6	9·5	11	11	9	15	18	20	11	11	8	11

The magnetic field at the centre of the coil = current \times 92.

One scale division = one five-millionth part of the length of the wire.

well cause variations in the readiness with which the arrangement would respond to a movement equivalent to less than one-tenth of a scale division. Nevertheless it is clear in spite of one or two discrepancies that a greater magnetising force is necessary to cause a sensible elongation when the load is great than when it is small. In one case, that of the thin wire under a load of 14 lbs., there was no evidence of any elongation. It is probable, judging by analogy, that a maximum elongation, too small, however, for the instrument to detect, would occur with a current of about 0.12 ampère. Whether any load, however great, would render the preliminary elongation of the wire too small to be measured by an ideally perfect instrument is uncertain.

The second determination could be made with far greater accuracy. But the load had the effect of flattening the apex of the elongation curve in such a manner that the actual maximum was not so sharply defined as in the case of free rods.

The third determination, that of the magnetising current under the influence of which the original length of the wire was unaltered, was susceptible of great accuracy, and was the most important for the purpose of the present investigation.

The measurement of the amount of retraction caused by a given strong current was also perfectly easy and certain.

The figures recorded in the table disclose the following facts:—

1. The effects produced by magnetisation upon the length of an iron wire stretched by a weight, are in general of the same character as those which have been shown in my former paper to occur in the case of a free iron rod. Under the influence of a gradually increasing magnetising force such a wire is at first elongated (unless the load be very great), then it returns to its original length, and finally it contracts.

2. The maximum elongation diminishes as the load increases according to a law which seems to vary with different qualities of iron. If the ratio of the weight to the sectional area of the wire exceeds a certain limit, the maximum elongation (if any) is so small that the instrument fails to detect it.

3. The retraction due to a given magnetising force is greater with heavy than with light loads.

4. Both maximum elongation and neutrality (*i.e.*, absence of both elongation and retraction) occur with smaller magnetising currents when the load is heavy than when it is light; retraction, therefore, begins at an earlier stage. Thus the anticipation expressed in my former paper is justified.

5. The effects both of elongation and of retraction are, as might be expected, greater for thin than for thick wires, and for soft than for hard iron.

Addition, April 3rd, 1886.

It would be difficult for anyone who has not actually seen the apparatus above described to appreciate its extreme delicacy, and the accuracy with which it is capable of measuring such minute quantities as would commonly be regarded as infinitesimal.* It has been suggested to me that greater value would be attached to the experimental results contained in the present and former papers if the manner in which they were arrived at were described in greater detail, and a few of the actual scale readings given in full.

In the case of the twelve series of observations to which the table given in this paper relates, my method of proceeding was as follows:—The iron wire having been placed in position and loaded with a weight, a short time was allowed for the apparatus to attain a nearly steady temperature. The reflected image of the indicating wire (which I will call the index) was then, by means of the fine screw adjustment, brought upon the upper half of the scale, the zero point of which was in the middle, and the index, which, owing to small variations of temperature†, was rarely absolutely at rest, was watched until its upper edge nearly coincided with one of the scale divisions. The number of this division was noted and recorded from my dictation, and at the instant when exact coincidence occurred, a contact key was depressed, which caused a current of 1·6 ampère to pass through the coil. The number of the scale division nearest to which the index was deflected was again noted and recorded as before; and if the point which the index reached happened to be exactly midway between two divisions, the reading was recorded to half a scale division. When the deflections were small, the readings were taken to the nearest half scale division; but this, though easy enough, was in general considered to be a needless refinement.

The next course was to find by a tentative method the strengths of the three currents which respectively produced—(1) the first sensible elongation; (2) the maximum elongation; (3) neither elongation nor retraction; and in order to do this, the resistance in the circuit was varied by means of a large set of coils, and a succession of currents of different strengths (perhaps from twenty to fifty in number, or sometimes even more) were caused to pass through the apparatus.‡

* The instrument was exhibited in action at the Soirée of the Royal Society, May, 1885.

† Taking the coefficient of expansion of iron to be 0·0000122 per degree C., the heat elongation due to a rise of temperature of one degree would produce a deflection of sixty-one scale divisions; but in addition to the iron there was a somewhat greater length of brass, and if this shared in the heat expansion, a total deflection of more than 150 scale divisions per degree would be produced.

‡ It is of course understood that the circuit was actually closed by the key only

These currents having been determined, the final step was to repeat the first observation of the retraction produced by the fixed current of 1·6 ampère, and thus to check the accuracy of the experiment. The subtractions of the readings were then made, and if there had been a difference of more than one scale division between the pre-

Retraction with Current of 1·6 Ampère.*

	Iron wire 1·2 mm.			
Preliminary readings . {	121 } 127 } 6	96 } 105 } 9	26 } 37 } 11	44 } 55 } 11
Final readings. {	101 } 107 } 6	108 } 118 } 10	22 } 33 } 11	25 } 36 } 11

	Iron strip.			
Preliminary readings . {	57 } 66 } 9	49 } 64 } 15	78 } 96 } 18	10 } 30 } 20
Final readings. {	61 } 70 } 9	28 } 43 } 15	47 } 65 } 18	-2 } 18 } 20

	Hard iron.		Soft iron.	
Preliminary readings . {	90 } 101 } 11	129 } 140 } 11	60 } 68 } 8	65 } 76 } 11
Final readings. {	92 } 103 } 11	135 } 136 } 11	70 } 78 } 8	36 } 47 } 11

liminary and the final result, it was my intention to repeat the series of observations. This, however, was not found necessary in a single instance. The actual figures as recorded in the note book are given above, the differences being the numbers which appear in the last line of the table in the paper. The agreement between the preliminary and the final readings, when a number of experiments had at the moment of making an observation, and for a period of not more than half a second at a time.

* In eighteen pairs of observations with iron there was exact agreement sixteen times and a difference of one scale division twice. With nickel the deflections were much larger, sometimes exceeding 100 divisions, and the agreement was not so close; but the discrepancy did not exceed two divisions.

intervened between them, is very remarkable, and could only have been attained, however perfect the instrument, by the method of observation which has been described, unless indeed the readings had been taken to fractions of a scale division.

In the course of my experience in working with the instrument, I have naturally become acquainted with a number of little devices, difficult to describe, which would give me an advantage over a novice in its use. But I believe that any competent manipulator would find it quite easy to obtain uniform and consistent results with it.

The efficiency of the apparatus is due partly to the perfection of the optical arrangements and partly to the fact that in the moving parts unnecessary lightness has not been acquired at the expense of sufficient massiveness and rigidity.

III. "Remarks on the Cloaca and on the Copulatory Organs of the Amniota." By Dr. GADOW. Communicated by Professor M. FOSTER, Sec. R.S. Received March 11, 1886.

(Abstract.)

The sphincter muscles of the anus of Crocodilia are differentiations of the postpelvic portion of the system of the m. rectus abdominis rather than of the true caudal muscles.

The copulatory muscles of the Carinatae are derived from the m. sphincter ani solely, whilst in the Ratitae they are also differentiations of muscles which are still attached to the pelvis, and are, therefore, skeleto-genital.

The mammalian sphincter ani does not take a share in the muscle supply of the copulatory organ, and thus exhibits a difference from Birds and Lizards.

Distinctly copulatory muscles in the Mammalia are derived from skeletal and from non-striped muscles. In this respect the Mammalia agree with Crocodilia and Chelonia.

Then the author describes the nerve-supply of the cloacal region in Crocodilia.

Third Chapter.—The modifications of the cloaca in the various chief groups of Amniota: *Crocodilia*, Lizards, Snakes, *Hatteria*, Birds, Tortoises, Mammals.

Lizards and snakes together represent a special type.

Hatteria comes nearest the Amphibia, or the embryonic condition of Sauropsida; bears, however, resemblance to the Lizards.

Chelonia represent a type somewhat intermediate between that of the Ratitae and Crocodilia and that of the Monotremata, at the same time bearing slight resemblance to that of the Sauria.

